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Streambank Erosion Mapping on the Nottoway River Using GPS-based Above-water Video

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This project concerns the development of streambank erosion maps on military installations utilizing GPS-based above-water video mapping and image georeferencing techniques. The river mapped was the Nottoway River at the Fort Pickett military installation on October 10-11, 2015. Kayak-mounted above-water cameras were utilized to capture georeferenced images of streambank erosion. These GIS-based erosion classifications were utilized to develop erosion maps for determining streambank erosion conditions along the river. Areas of high erosion were identified as about two percent of the river (2167 ft. of streambank length). These maps allow for the opportunity to revisit the sites to determine changes in streambank erosion due to human impacts. Three sites (encompassing 1118 ft. of streambank) were determined to be areas of high erosion, for future river rehabilitation.

Introduction

An increase in human development in close proximity to a river can significantly affect its ecosystem (Castro and Reckendorf, 1995). Roads, bridges, and dams have a particularly extreme effect on the water quality of rivers, affecting flow rate, substrate composition, and chemical make-up (EPA, 2016). The Nottoway River in Virginia runs through the Fort Pickett Army National Guard installation (Virginia National Guard) and is home to two at-risk species, *Percina rex* and *Fusconaia masoni*. The *Percina rex*, known by the common name Roanoke Logperch, is a small freshwater fish of the darter species endemic to North Carolina and Virginia and endangered federally and state-wide (U.S. Fish and Wildlife Service). The Roanoke Logperch serves as an indicator species of rivers with turbidity, as it feeds on the substrate. The latter, the *Fusconaia masoni*, or Atlantic Pigtoe, is a native endangered freshwater mussel known for filtering water (Wolf, 2010). High activity levels around and through the Nottoway River due to military exercise necessitate knowledge of the levels of erosion within the installation, in order to control future erosion and protect aquatic species.

Sediment is the biggest pollutant of our rivers systems in the United States (EPA, 2000). A key source of nonpoint sediment pollution is streambank erosion, with approximately 80% of sediment loading within bodies of water being due to erosion (Sass and Keane, 2012). In addition to the harmful effects of erosion on environmental aquatic species and biodiversity, Sass and Keane (2012) discovered that erosion of streambanks also causes decreased freshwater supply, enlarged water treatment costs, increased water temperature, decreased dissolved oxygen concentrations, decreased river recreational value, and increased likelihood of flooding. These impacts are difficult to remediate, and immediate prevention is the best way to stop future habitat degradation and water quality issues (FAO).

The pollution within the Nottoway River creates concern due to the aquatic endangered species that reside there, thus steps must be taken to reduce sediment pollution to preserve biodiversity and protect these endangered species (Fidan et al., 2016). Van Eps et al. (2004) utilized a graphical method of quantifying bank erosion rates and sediment yield. Factors that were studied within their project included using bank angle, root depth, and bank material to determine erosion potential based on a bank erosion hazard index and near-bank shear stress analysis. Similarly, Evans et al. (2003) developed a GIS based technique to produce a watershed model and predict streambank erosion rates. Although these quantitative methods of streambank analysis proved to be accurate and inventive, the biggest limitation was time and resources during the data collection process. Therefore, the goal of this project is to conduct a more rapid analysis of streambank erosion so that immediate action can be taken towards remediation of high erosion areas.

Improvements in the intersection of technology and nature allow for a comprehensive and technical approach to collecting data about streambank erosion condition. Technology for this project includes: Global Positioning System (GPS), camera systems, data-combining hardware, digital video recording and ArcGIS (ESRI) mapping software. The use of these advanced systems allows the efficient collection of a thorough stream of information which was used to classify each point on the Nottoway River according to a streambank erosion index. The streambank erosion map utilizes factors like GPS and levels of current erosion based on visual images on both sides of the river and presents it in a user-friendly, map-based format.

Overall, protecting natural resources while promoting human and military development is crucial to sustaining military installations. Understanding the impact of military training on river streambanks is needed to promote the protection of natural habitat and abide by the EPA's total maximum daily load (TMDL) regulation (Hensley, K.J., 2014). With the rapid analysis of areas with high erosion, future stream rehabilitation can take place promptly.

Justification and Objectives

The purpose of this research is to create a comprehensive database for all the information pertaining to streambank erosion conditions on the Nottoway River through the Fort Pickett installation. The goal is to determine current areas of georeferenced high, medium, and low erosion so that large volumes of erosion can be controlled in the future. Thus, the basis conducted within this study was that streambank areas that have been eroding will continue to increase erosion loads in the future, unless action is taken to inhibit further erosion. These data were organized into a report as well as a user-friendly map system linking river streambank data and captured video to a GPS location. This project will provide the knowledge necessary to aid the U.S. Department of Defense in making decisions to avoid further streambank erosion with the continued use of any part of the Nottoway River and Fort Pickett military base, as well as further military installations. Additionally, this technology will provide a rapid means of analyzing future river systems for streambank erosion due to the simplistic equipment set-up, nontechnical means of determining erosion along a river, and user-friendly map layout of data.

Equipment

The Above-water Video Mapping System (AVMS) utilized was developed at the University of Tennessee to examine river ecosystems and record their location using a differentially corrected GPS. Two instrumented kayaks were used to float the 10.3 mile section of Nottoway River. A Wilderness Systems Tarpon 100 kayak (Figure 1) is used to float through the deepest (thalweg) section of the creek or river. Mounted to the bow of this kayak are two Contour video cameras with one angled at the left stream bank and one at the right stream bank (Figure 2). An additional, front-facing Splashcam Deep Blue (Ocean Systems Inc.) video camera was mounted to the bow, acquiring above-water footage of river characteristics and streambanks (Figure 3). A weather proof case located at the rear of the kayak contained a 4-channel Mobile Digital Video Recorder (DVR) (Super Circuits), a Garmin GPS 18 receiver (Garmin Ltd.), an Acumen Instruments Serial Data Recorder (Acumen Instruments), and a Noland NM42 NMEA 0183 Multiplexer (Noland Engineering).

Mobile DVR's were used to collect the georeferenced digital video images. River depth measurements were recorded utilizing the CruzPro flush-mounted depth sensor (CruzPro Ltd.). The float path was attempted through the main section of the river, otherwise identified as the thalweg (Figure 1).

Figure 1
Instrumented kayaks floating the river thalweg.

Figure 2
Above water Contour cameras that were mounted to the bow of the kayak and pointed towards the left and right banks.

Figure 3
Above water camera on the bow of the kayak and pointed directly toward the front to capture video data of river characteristics.

The Mobile DVR is a spatial multimedia system that integrates GPS and video images, so each picture has a location. The DVR system includes hardware that will sync video images with the embeded GPS data.

The Garmin 18 is a 12 channel, high performance meter GPS receiver. It has a combination GPS receiver and satellite differential correction receiver in the same housing. The user can program which NMEA (National Marine Electronics Association) 0183 strings are output. The receiver is programmed to output $GPRMC and $GPGGA NMEA 0183 data strings once every second. The $GPGGA string contains time, latitude, longitude, GPS quality (2D/3D fix and differential correction), number of satellites, horizontal dilution of precision (HDOP), and altitude. The $GPRMC string has time, latitude, longitude, speed over ground, course over ground, date, and magnetic variation. Position accuracies of approximately one meter are consistently attainable. Using the

NMEA multiplexer and Serial Data recorder, the GPS output and the depth sensor measurements were recorded at a 1 Hz sampling frequency. The Mobile DVR Digital Video Recorder features audio/video and GPS input.

The georeferenced attributes of the streambank were manually classified by reviewing the digital images and field notes. GIS river streambank erosion maps were developed in ArcGIS 10.1. Aerial photography integrated within ArcGIS was utilized as background maps. Above-water video was viewed to define the river's streambank erosion (low, medium, high) based on the Streambank erosion characteristics (Figure 4).

Streambank Erosion Characteristics of the River		
Erosion Parameter	Description	Example
Low	The streambank is characterized with a growth of vegetation, small bank angle, and short bank height.	
Medium	The bank contains little vegetation, slightly elevated bank angle, and/or a raised bank height.	
High	The area is characterized with no vegetation, large bank angle, and elevated bank height.	

Figure 4
Streambank erosion characteristics.

Procedure

The main section of the current in a river, known as the thalweg, was the float path taken while mapping the Nottoway River. Over the 2-day survey period the river discharge rates were measured between 80 and 95 cfs at the USGS 02044500 gage (Figure 5), this aided in understanding the stream flow and river conditions throughout the Nottoway River. The survey of the Nottoway

River was from the dam at Highway 46 to the bridge at Highway 613, approximately 10.3 miles. The kayak-mounted above-water video mapping system was used to collect the georeferenced video images. Each video recorder captured real time video footage simultaneously with the GPS data obtained from the Garmin 18 GPS sensor. The river's streambank erosion characteristics (low, medium, high) were determined during video review sessions in the lab and the time codes associated with these characteristics were put into a spreadsheet. The GPS track log with attribute data was merged into ArcGIS and queried to locate areas of high erosion.

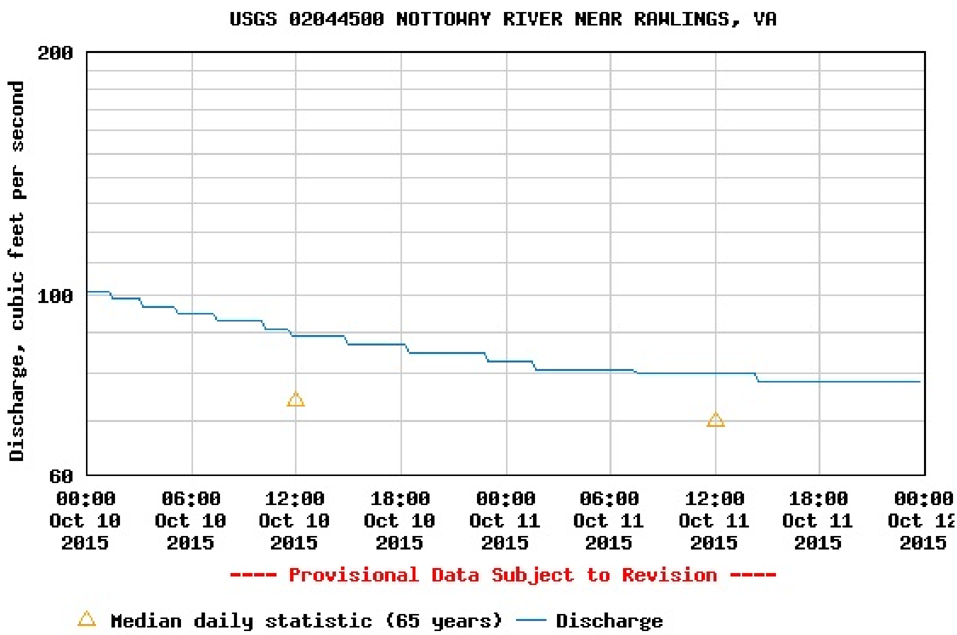

Figure 5

USGS gage flow rates represent the decreasing discharge rate of the Nottoway River throughout the two-day time period that data was being collected.

Results

The GPS tracklog collected at a 1 Hz interval (Figure 6) accurately follows the Nottoway River shown in aerial photography. The right bank erosion map (Figure 7) reveals that areas of high erosion volumes are located in the bends of the Nottoway River. Additionally, Figure 8 shows the left streambank, representing the high erosion volumes that are dispensed along the bends of the Nottoway River.

As shown in Table 1, the areas of high erosion along the Nottoway River within the left and right bank are approximately 1053 ft. and 1114 ft., respectively.

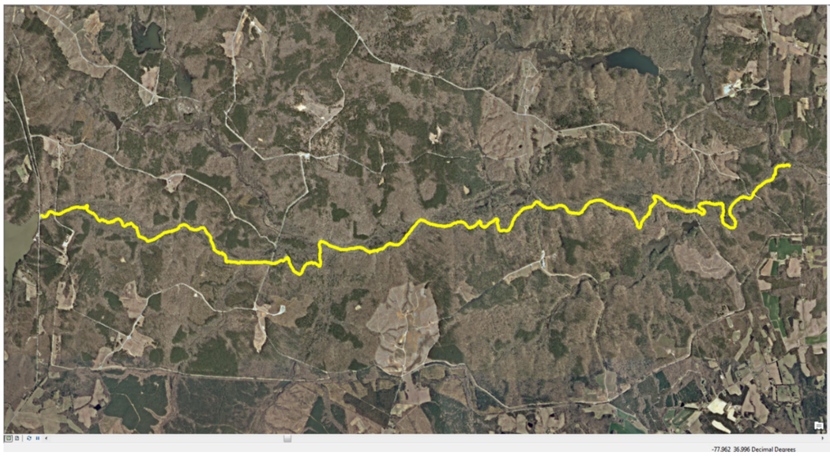

Figure 6
GPS Tracklog of the Nottoway River.

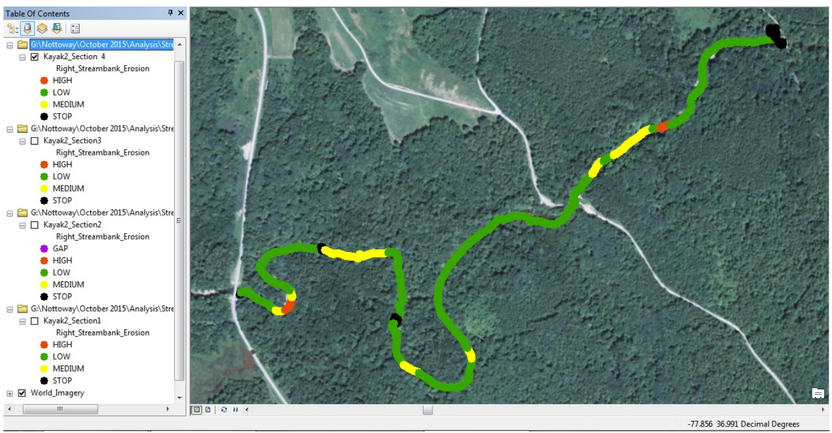

Figure 7
Right bank erosion map of the final kayaked section on the Nottoway River, in which the red, yellow, green colors denote high, medium, and low levels of erosion, respectively.

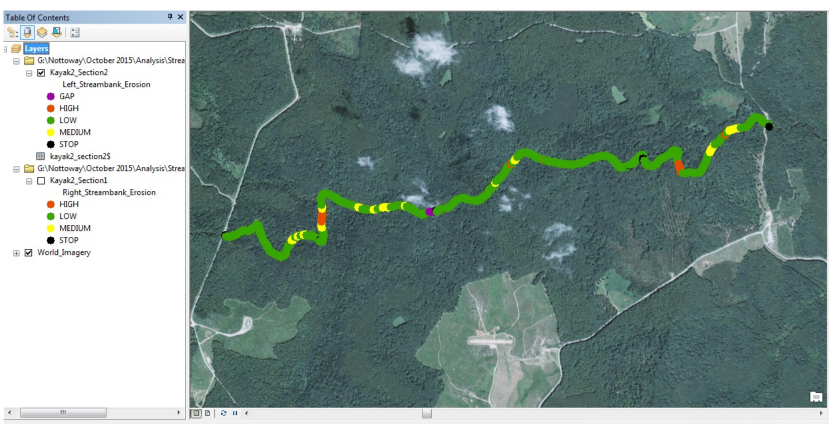

Figure 8
It is highlighted along the left streambank within the Nottoway River that areas of high erosion are grouped together in sections. The non-uniform distribution of high erosion areas is identified in Table 1.

	Distance (ft.) for areas of high erosion	Distance (ft.) for areas of medium erosion	Distance (ft.) for areas of low erosion	Total distance (ft.) along river
Left bank	1053.5	6247.4	43964.5	51275.4
Right bank	1114.2	5964.7	44205.4	51284.3

Table 1

Areas of high, medium, and low erosion on the Nottoway River are represented by quantifying the distance they occupy along the river.

Discussion

Once all points of high erosion were evaluated along the Nottoway River, the data were analyzed geographically for large areas of high erosion. Three continuous areas of the river were identified as having high erosion, as highlighted in Table 2. For the protection of endangered aquatic species and the reduction of future sediment pollution, these streambank areas should be rehabilitated.

Site	Length of area (ft.)	Latitude (°N)		Longitude (°W)
1	374	from	36.9856	77.9174
		to	36.9848	77.9175
2	268	from	36.9887	77.9496
		to	36.9887	77.9489
3	476	from	36.9875	77.9470
		to	36.9870	77.9460

Table 2

Sites of high streambank erosion are identified and highlighted for future rehabilitation work.

Conclusion

Protecting natural resources while maintaining human development is critical to sustaining the human expansion and preserving biodiversity. Understanding the impact of human development on aquatic habitats is necessary to promote the protection of the natural habitat, keep the water system clean, and control future erosion dispense (USGS, 2016). Above-water video erosion mapping involves conducting surveys of river and creek reaches (sections) to develop state-of-the-art geospatial maps of streambank erosion. Key attributes mapped are distance and streambank erosion. Along the 10.3-mile section of the Nottoway River, two percent of the total length was identified as high erosion areas. This technology proved to be an invaluable tool for managing the streambanks of the Nottoway River, and could have resourceful applications at other sites requiring the characterization and mapping of streambank erosion. Although observer bias and qualitative erosion analyses are limitations of this study, the project provided a thorough and systematic means of determining areas of erosion; additionally, future efforts with this technology should be taken to analyze data in a quantitative yet rapid manner. Overall, the purpose of this study was to develop a rapid method of erosion analysis so future efforts to remediate streams and to control sediment pollution could be done immediately and with less technical resources. Implementing such a technology in a situation like that at Fort Pickett installation on the Nottoway River, would allow sediment pollution to be controlled and regulated to EPA standards, biodiversity of the endangered species to be protected, and future military work to be conducted in areas that would not create future detriment to streambank erosion.

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